Single Phase Harmonic Limits

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Abstract

The International Electrotechnical Commission (IEC) sets limits for harmonics in the current of small single-phase or three-phase loads, less than 16 A per phase, in *Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions* (IEC 61000-3-2). The IEEE Single Phase Harmonics Task Force (P1495) is developing a similar standard for single phase loads of less than 40 A. There is, however, still no agreement on what such limits should be, or whether limits are even needed.

Electric utilities are concerned about the effects of harmonics on their systems: telephone noise, excessive heating of transformers and other equipment, capacitor damage, and others, and would like to limit the levels of harmonics produced by loads on their systems. Manufacturers, however, are concerned about the cost of changes to their equipment to reduce harmonic production. This paper summarizes the IEC limits and the proposed IEEE limits, discusses the need for single phase harmonic limits, and presents what those limits might be.

Introduction

Harmonic currents in the power distribution system can cause:

- Transformer heating
- Transformer secondary voltage distortion
- Increased power losses
- Overloaded neutrals and capacitors
- Telephone and communication system noise

Existing penetrations of small single phase loads can create problems that require mitigation [1].

There are two ways to address the harmonics issues. The first is the traditional method of mitigating problems after they adversely affect utilities and their customers. Mitigation options include:

- Installing k-factor or derated transformers
- Oversizing neutrals and capacitor ampacity
- Detuning resonant circuits
- Appling passive or active filters

The mitigation expense is usually borne by those owning the equipment causing the harmonic problem, or by those affected by it.

This mitigation philosophy accepts that part of the electrical load is harmonic and must be served. This philosophy accepts the increased losses caused by harmonics, which raises the question of whether utilities should charge for harmonic consumption, as they now charge for reactive power. The drawback to the mitigation philosophy is that nothing is done until after a problem arises, and the costs to those affected by the harmonics can be high before the problem is solved.

The other option for addressing harmonics problems is to limit consumption of harmonic currents by changing the design of the loads. This limiting philosophy says that we have a constant frequency power system, and that loads should be limited in their consumption of other frequencies.

The limiting philosophy affects mostly computer and other electronic equipment, because the rectifier power supplies in those devices now consume high levels of harmonic current. Many manufacturers oppose limits because. Competition with other manufacturers is not the issue; the standards apply to all. But limits require additional investment, and the return on that investment is low; the change to low-distortion supplies does not increase company profits.

International Electrotechnical Commission (IEC) Standards

The IEC, which governs the European Union, adopted a philosophy of requiring manufacturers to limit their products' consumption of current harmonics in their standard IEC 61000-3-2 [2]. This standard applies to all single-phase and three-phase loads rated at less than 16 A per phase. Products must be tested in approved laboratories to insure they meet the standard. 61000-3-2 took effect on January 1, 2001, although enforcement seems to be limited.

The standard classifies electrical loads as shown in Table 1. The standard as originally published used the classifications on the left side of this table, with the special waveshape defined by Fig. 1. The special waveshape is the limiting envelope for the current waveshape. The current has to fall within this waveshape for each half cycle 95% of the time.

After negotiations with manufacturers opposed to the limits, Amendment A14, with its classifications on the right side of the table, was published, and manufacturers have three years in which they could use either set of classifications [4]. After January 1, 2004, Amendment A14 will be in force.

The harmonic current limits for each class of equipment are shown in Tables 2-5. Note that these limits are for individual harmonics, and do not specify total harmonic distortion (THD). For 230 V Class D equipment (PCs, PC monitors, and television receivers) rated less than 600 W, the distortion in a waveform that has the maximum allowable distortion at each harmonic is 95% at present.

EN 61000-3-2 Classifications	Amendment A14 Classifications
Class A: Balanced 3 phase equipment, single phase equipment not in other classes	**Class A:** Balanced 3 phase equipment; household appliances excluding equipment identified as Class D; tools (except portable), dimmers for incandescent lamp (but not other lighting equipment), audio equipment; anything not otherwise classified
Class B: Portable power tools	**Class B:** (no change)
Class C: Lighting Equipment over 25 W	**Class C:** All lighting equipment except incandescent lamp dimmers.
Class D: Not Class B or C, single phase, not motor driven, under 600 W, and possessing the "special waveshape."	**Class D:** Single phase, under 600 W, personal computer, PC monitor, TV receiver.

Table 1. IEC 61000-3-2 load classifications [3].

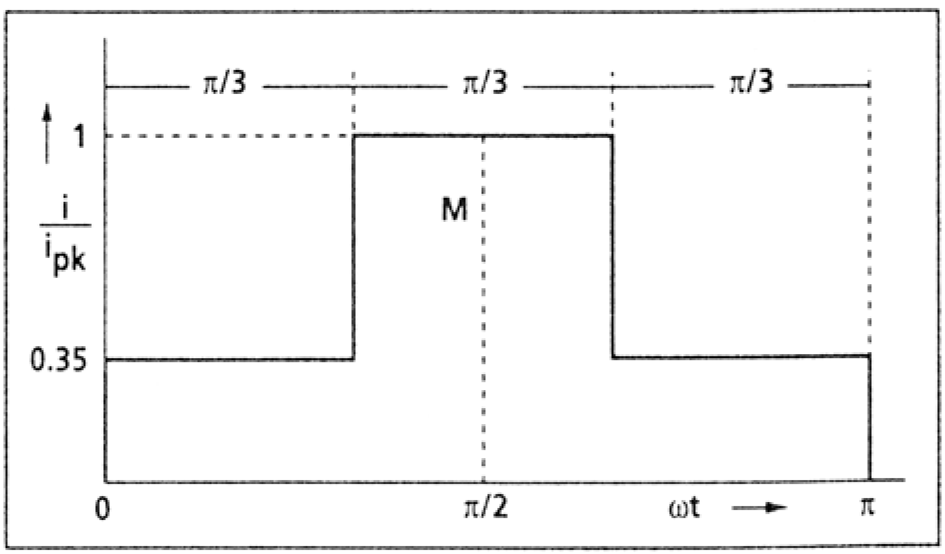

Figure 1. Special waveshape [3].

Harmonic order n	Maximum permissible harmonic current (A)
Odd harmonics	
3	2.30
5	1.14
7	0.77
9	0.40
11	0.33
13	0.21
$15 \leq n \leq 39$	2.25/n
Even harmonics	
2	1.08
4	0.43
6	0.30
$8 \leq n \leq 40$	1.84/n

Table 2: Limits for Class A Equipment [3].

Harmonic order n	Maximum permissible harmonic current (A)
Odd harmonics	
3	3.45
5	1.71
7	1.155
9	0.60
11	0.495
13	0.315
$15 \leq n \leq 39$	3.375/n
Even harmonics	
2	1.62
4	0.645
6	0.45
$8 \leq n \leq 40$	2.76/n

Table 3: Limits for Class B Equipment [5].

Harmonic order n	Maximum permissible harmonic current (% of fundamental)
2	2
3	30 x circuit power factor
5	10
7	7
9	5
$11 \leq n \leq 39$	3

Table 4: Limits for Class C Equipment [6].

Harmonic order n	75 W < P < 600 W Maximum permissible harmonic current (mA/W)	P > 600 W Maximum permissible harmonic current (A)
3	3.4	2.30
5	1.9	1.14
7	1.0	0.77
9	0.5	0.40
11	0.35	0.33
13	0.296	0.21
$15 \leq n \leq 39$	3.85/n	2.25/n

Table 5: Limits for Class D Equipment [7].

US Standards

A number of differences between European and US power systems [8] suggest that any harmonic limits for the US should be different from the IEC standard. The European system uses no neutral on overhead medium voltage distribution and a cable sheath for the underground portion, and they use delta wye transformers to step down the voltage to 400/230 V. As a result, it is less susceptible to triplen (3, 6, 9…) harmonic distortion than the US system. The European system includes extensive 400/230 V secondary distribution, creating higher-impedance utility distribution than the US system. The US system has higher secondary impedance beyond the point of common coupling, however, because of smaller distribution transformers used.

Draft IEEE Guide

IEEE considered these differences, and studies that relate distribution current distortion to voltage distortion [9, 10], IEEE has drafted a guide to limit harmonic current consumption by single-phase loads rated less than 600 V and 40 A [8]. This draft guide divides the loads into two classes:

1. "Higher wattage nonlinear loads like heat pumps and EV battery chargers as well as large concentrations of lower wattage devices like computer workstations and electronic ballasts found in typical commercial offices and businesses. [8]" The recommended maximum levels of current distortion allowed for these loads are shown in Table 6. The guide also suggests a minimum power factor of 0.95 for the high wattage loads.

Maximum THD_I	15%
Maximum 3rd harmonic current	10%

Table 6. Recommended harmonic current limits.

2. "Lower wattage nonlinear loads not concentrated in a small area. [8]" Table 7 shows the recommended limits, which are double the values in Table 6, for these loads.

Maximum THD_I	30 %
Maximum 3rd harmonic current	20 %

Table 7. Recommended harmonic current limits.

Other US Standards

Because of high concentrations of computers in their offices, the US Social Security Administration adopted a limit of 15% current THD for computers purchased after 1999 [8]. While computer vendors are not meeting this limit, they are supplying computers that draw about 35% current THD, far better than the 90-100% current THD of most computers purchased today.

The California Energy Commission, working with the National Electric Vehicle Infrastructure Working Council, adopted standards for electric vehicle battery chargers [8]. These limit current distortion to 20% THD and specify a minimum power factor of 0.95. Charger vendors have met these requirements.

The Future of Harmonic Current Limits in the US

Some US manufacturers oppose harmonic current limits. The question is, which option for addressing harmonic problems creates the lowest societal cost? Research is needed to answer this question, which includes:

- Cost of mitigating problems as they arise
- Cost of lost production caused by harmonic problems before they are solved
- Cost to manufacturers to meet proposed limits

Further technical research on acceptable levels of distribution current harmonics, and how those relate to harmonic consumption of individual loads.

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